STUDIES ON STABILIZATION OF EXAPANSIVE SOIL USING CEMENT AND FLYASH

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ABSTRACT

Expansive soils possess undesirable engineering behaviour such as low bearing capacity, high shrinkage and swelling characteristics. It forms poor subgrade material due to low CBR values and hence excessive pavement thickness is required for designing flexible pavement. Ground improvement techniques such as soil stabilization are employed to improve the bearing capacity and to control volume change in expansive soils. The most commonly used method is addition of stabilizing agents such as lime or cement to the expansive soil. In developing countries like India, industrialization has led to the generation of large amount of fly ash, which poses a great challenge for its safe disposal without affecting the environment. In addition, the increasing cost of traditional stabilizing agents and the need for the economical utilization of industrial waste has paved way for an investigation into the stabilizing potential of fly ash in expansive soil. Hence, the present study focuses on the assessing the suitability of stabilized expansive soil with cement and fly ash for subgrade in flexible pavement. Cement was added to expansive soil at 0-4%. The percentage of fly ash, which is used in the present study, is varied from 0-8%. Test specimens were subjected to Atterberg limits, Differential free swell, Standard Proctor Compaction and CBR tests. This research helps to assess the behaviour of expansive soil mixed with cement and fly ash independently. Based upon the favourable results obtained, it can be concluded that the expansive soil can be successfully stabilized with cement or fly ash.

Keywords: *Expansive soil, Cement, Fly ash, Compaction Characteristics, CBR.*

INTRODUCTION

Expansive soils cover nearly 20% of the land mass in India including Deccan plateau, Western Madhya Pradesh, parts of Gujarat, Andhra Pradesh, Uttar Pradesh, Karnataka, Tamilnadu and Maharashtra. These soils have the tendency to increase in volume when the water is available and decrease in volume when the water is removed. This typical swelling/shrinkage behavior is due to the basic mineral composition of montmorillonite. These soils used as a sub grade material forms the integral part of road pavement construction. Road pavement undergoes structural and constructional damages due to alternate expansion and contraction of the soil caused by fluctuations in the moisture content. Geotechnical Engineers can avoid the above said soil problems by three ways (i) Replacing the expansive soil with another soil of superior quality (ii) Modifying the properties of expansive soils with additives (iii) Accepting the limitations of expansive soil and designing the pavement with high factor of safety. Among them, the second method had been proven as the most effective method, which also termed as soil stabilization. Additives such as lime, cement, Ferric chloride, rice husk, Bagasse ash and fly ash are used to improve the strength characteristics and reduce the swell potential characteristics.

CEMENT STABILIZATION

The interaction of cement with expansive soil is explained in Schaefer et al (1997) as follows:
The Portland cement consists of tricalcium silicate (C3S) dicalcium silicate (C2S), tricalcium aluminates (C3A) and tetra calcium alumina ferrite (C4A) as major constituents. Whenever the cement is added to the soil, the pore water in the soil reacts with cement and hydration of cement occurs. The hydration of cement produces hydrated calcium silicates, hydrated calcium aluminates, and hydrated lime. The first two of hydration products are major cementitious products bind the adjacent cement grains together during hardening and form a hardened skeleton matrix, which encloses unaltered soil particles. Further the hydration of cement leads to rise of PH value of water. The soil minerals such as silica and alumina is dissolved in water and the above hydrous minerals gradually react with calcium ions liberated from the hydrolysis of cement (pozzolonic reaction) and form insoluble secondary cementitious products which harden when the soil sample is cured for specified number of days, resulting stabilization of natural soil.

FLYASH STABILIZATION

Fly ash is a waste material obtained from thermal power plants. It is extracted from flue gases of a furnace fired with coal and it is non-plastic fine silt. Fly ash consists of hollow spheres of silicon, aluminium, iron oxides and unoxidized carbon. Fly ash can provide an adequate array of divalent and trivalent cations (Ca2+, Al3+, Fe3+ etc) under ionized conditions that can promote flocculation of dispersed clay particles. The strength characteristics of fly ash stabilized clays are measured by means of unconfined compressive strength or California Bearing Ratio (CBR) values.

LITERATURE REVIEW

The usage of cement and fly ash as a stabilizing agent in expansive soils is investigated by several researchers. Christensen, A.P., (1969) studied the effects of cement on properties such as plasticity characteristics, volume change, unconfined compressive strength and CBR in expansive soils. It was concluded that addition of cement reduces plasticity and volume change characteristics and increases unconfined compressive strength. Erdal Cokca (2001) conducted experiments to examine the effects of high-calcium and low-calcium class C fly ash on basic properties of expansive soil such as such as grain size distribution, activity, plasticity index and swelling potential. It was concluded that the fly ash can be recommended as effective stabilizing agents for improvements of properties in expansive soil. Pandian et al (2002) carried out experimental studies on utilization of class C fly ash and class F fly ash on the CBR characteristics of black cotton soils. It was concluded that the addition of fly ash to black cotton soils increases CBR up to certain optimum level beyond which there is a decrease in CBR. Addition of fly ash results pozzolonic reactions, which increases the unconfined compressive strength. Phanikumar et al (2004) studied the effect of fly ash on free swell index, swelling pressure, swell potential, plasticity, compaction, strength and hydraulic conductivity in expansive soils by varying its percentage from 0 to 20%. It was concluded that plasticity, hydraulic conductivity and swelling properties are decreased with an increase in fly ash content. However, there is an increase in maximum dry unit weight and undrained shear strength with the addition of fly ash. Gyanen. Takhelmayum (2013) carried out experimental study on combined effect of fine and coarse fly ash mixtures on properties such as compaction characteristics and undrained shear strength in expansive soil. The percentage of fine and coarse fly ash mixtures, which is used in black cotton soil, is varied from 5-30%. It was concluded that the maximum dry density occurs at 95% soil and 5% fly ash mixture. The peak shear strength attained by fine fly ash mixture is 25% more when compared to coarse fly ash mixture.

MATERIALS

The expansive soil used in the present investigation was collected from Velachery in Chennai. The soil is dark grey to black in colour with high clay content. Grain size analysis and Atterberg limit tests were performed to classify the soil. The test results of grain size analysis are presented in Table 1. Based on the grain size distribution and Atterberg limits, soil is classified as CH. The fly ash used in present study was collected from North Madras Power Plant in Ennore, Chennai. The cement used in the present study belongs to Zurai cement 43 grade.

EXPERIMENTAL INVESTIGATION

The following tests were conducted on expansive soil and expansive soils stabilized with cement and fly ash of different percentages as per IS: 2720.

i. Atterberg Limit Test
ii. Differential Free Swell Test
iii. Standard Proctor Compaction Test
iv. CBR Test

The Atterberg limits such as liquid limit, plastic limit and shrinkage limit of expansive soil with varying percentages of cement and fly ash independently as per standard procedures. The test results are summarized in Table 2.

The differential free swell test was performed on the expansive soil stabilized with cement and fly ash at different percentages. The differential free swell is expressed as follows

$$\text{Differential free swell (\%)} = \frac{V_W - V_K}{V_K} x100$$

Where V_w and V_k are the volume of soil in water and kerosene respectively. The measured values of differential free swell are shown in Table 3.

Standard Proctor compaction tests were conducted on cement and fly ash blended with expansive soil with varying percentages on a dry weight basis. The test results are shown in Table 4. The soaked CBR tests were performed on soil samples prepared at the optimum moisture contents and maximum dry densities obtained from standard proctor compaction tests. The soaked CBR test results are presented in Table 5

RESULTS AND DISCUSSION

The laboratory tests (Atterberg limit, Differential Free Swell, Compaction and Soaked CBR) were carried out on expansive soil. The stabilization of expansive soil with cement and fly ash is carried out by blending the soil with different percentages and the above tests were repeated. The measured characteristics are presented in Figs. 1 and 2.

Effect of cement and fly ash on Atterberg limits

The effect of cement and fly ash on Atterberg limits of expansive soil is presented in Fig. 1. The liquid limit decreases and the plastic limit increases marginally with an increase in both cement and fly ash content. The maximum reduction in plasticity index is about 11.6%, when the added cement content is 4%. The increase in shrinkage limit and shrinkage ratio is 202% and 28.1% respectively with the addition of cement content by 4%. It is observed that the increase in shrinkage limit is marginal beyond the fly ash content of 4%. As the fly ash content increases from 0 to 4%, the shrinkage limit increases by 93%; when the fly ash content was increased to 8%, The shrinkage limit increases only by 103%.

Effect of cement and fly ash on Differential Free swell

The measured values of differential free swell, for blends of different cement and fly ash contents are shown in Fig. 2(a). The differential free swell of expansive clay decreases with an increase in both cement and fly ash. It reaches one-third of the initial differential free swell of the soil at 4% of cement content. A maximum reduction of 85% is observed with the addition of 8% of fly ash.

Effect of cement and fly ash on Compaction characteristics

The variation of maximum dry density with an increase in percentage of cement and fly ash based on standard proctor compaction test is shown in Fig. 2(b). Among the various percentage of cement used, the dry density is found to be maximum for 4% cement in the mix, whereas optimum moisture content increases by 15.4% (Table 3) at 4% cement content.. It can be observed that, the maximum dry density decreases by about 2.5% at 8% fly ash content. The decrease in maximum dry density with the increase in percentage of fly ash can be attributed to the lower value of specific gravity of fly ash in comparison with expansive soil.

Effect of cement and fly ash on CBR

The California Bearing Ratio (CBR) is an indicator of strength and load carrying capacity of the soil, which will assist the designer in recommending or rejecting the soil as suitable for sub grade in a flexible pavement. The soaked CBR test results are presented in Fig. 2(c). From the test results, it is observed that the magnitude of CBR increases by 287% and 478% with the addition of cement content 2% and 4% respectively. The maximum increase in CBR is found to be 47.8% with the addition of 8% fly ash.

CONCLUSIONS

The stabilization of expansive soil with cement and fly ash independently is investigated and the effect of stabilization on the geotechnical properties of expansive soil is presented. The following conclusions can be drawn based on the analysis of results.

- The addition of cement and fly ash to expansive soil decreases the maximum dry density of the soil irrespective of their percentages.
- The properties such as plasticity index, shrinkage limit and differential free swell of the expansive soil decreases with the increase in percentage of cement and fly ash.
- The soaked CBR of the expansive soil increases with increase in cement and fly ash content.

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Table 1: Basic Components of expansive soil

S.No	Description	Results
1	Gravel	0%
2	Sand	9.6%
3	Silt & Clay	90.4%

Table 2: Atterberg limits of Soil- cement & Soil- fly ash mixtures

S.No	Soil Mix	Liquid limit (%)	Plastic limit (%)	Plasticity Index (%)	Shrinkage limit (%)	Shrinkage ratio
1	Soil alone	57	20.9	36.1	7.64	2.10
2	Soil+ 2% cement	56.7	21.0	35.7	14.76	1.62
3	Soil+ 4% cement	56.1	21.1	35.5	15.51	2.02
4	Soil+ 4% fly ash	55.4	21.3	34.1	16.35	1.74
5	Soil+ 8% fly ash	54.1	22.2	31.9	23.06	1.51

Table 3: Differential free swell test results

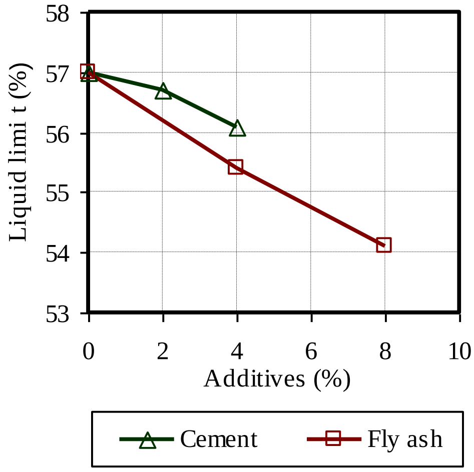
S.No	Description	Differential free swell (%)
1	Soil alone	166.67
2	Soil+ 2% cement	157.14
3	Soil+ 4% cement	50.00
4	Soil+ 4% fly ash	37.50
5	Soil+ 8% fly ash	25.00

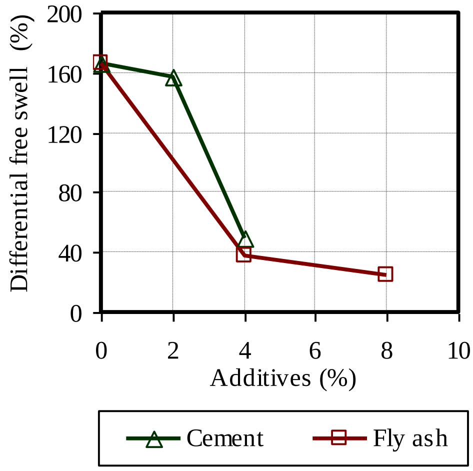
Table 4: Compaction characteristics of Soil- cement & Soil- fly ash mixtures

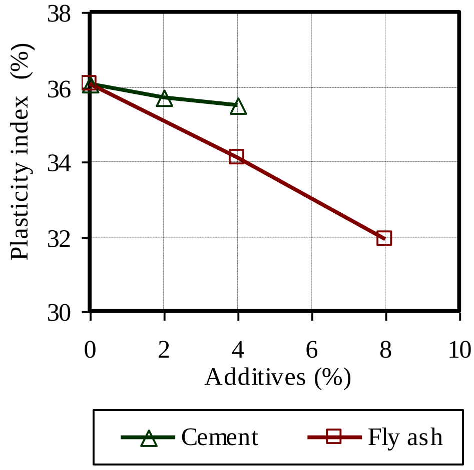
S.No	Soil Mix	Maximum dry density (gm/cc)	Optimum moisture content (%)
1	Soil alone	1.68	26
2	Soil+ 2% cement	1.60	24
3	Soil+ 4% cement	1.61	30
4	Soil+ 4% fly ash	1.63	18
5	Soil+ 8% fly ash	1.64	18

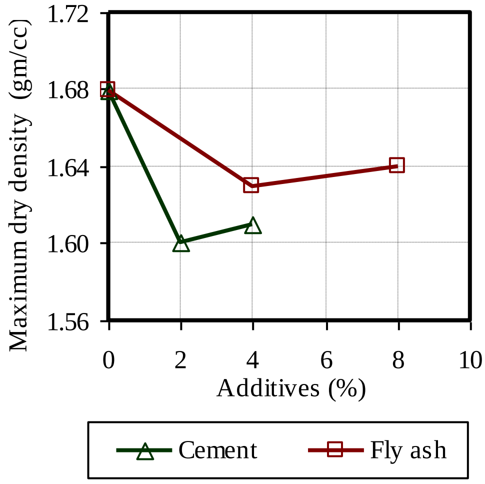
Table 5: CBR of Soil- cement & Soil- fly ash mixtures

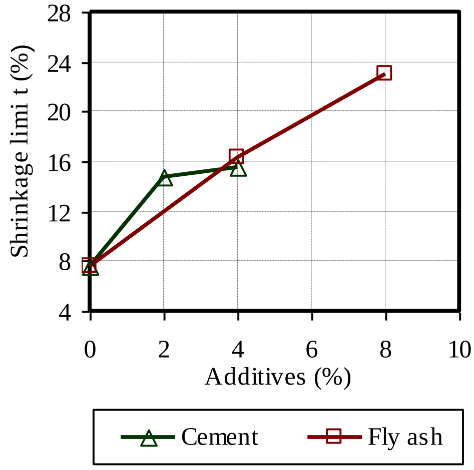
S.No	Description	CBR (%)
1	Soil alone	6.94
2	Soil+ 2% cement	26.84
3	Soil+ 4% cement	40.10
4	Soil+ 4% fly ash	7.5
5	Soil+ 8% fly ash	10.26

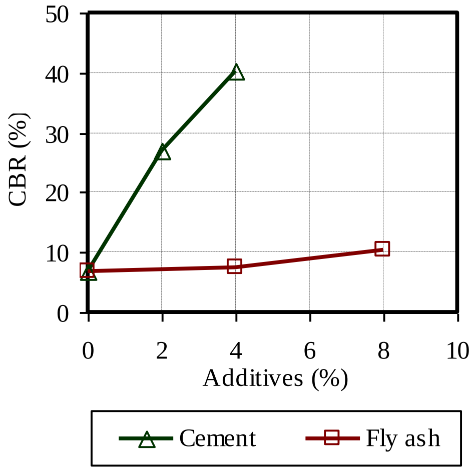

Liquid limi t (%)
58
57
56
55
54
53
0
2
4
6
8
10
Additives (%)
Cement
Fly ash


Differential free swell (%)
200
160
120
80
40
0
0
2
4
6
8
10
Additives (%)
Cement
Fly ash


Plasticity index (%)
38
36
34
32
30
0
2
4
6
8
10
Additives (%)
Cement
Fly ash


Maximum dry density (gm/cc)
1.72
1.68
1.64
1.60
1.56
0
2
4
6
8
10
Additives (%)
Cement
Fly ash





(c)

(c)

Fig. 1: Variation of (a) Liquid limit (b) Plasticity Index (c) Shrinkage limit as a function of cement and fly ash content

Fig. 2: Variation of (a) Differential free swell (b) Maximum dry density (c) CBR as a function of cement and fly ash content